Strategic Implementation Plan (SIP) for a Community-based Unified Forecast System

CAM *Working Group*

Presented by

Curtis Alexander, ESRL/GSD

Presented at SIP Coordination Meeting

May 14-16, 2019; College Park, MD

CAM WG *Membership*

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- ***Louis Wicker (NSSL)****
- *Jack Kain (NCEP/EMC)***
- *Lucas Harris (GFDL)***

- Eric Rogers (NCEP/EMC)
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- Jamie Wolff (NCAR/DTC)

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- **Andy Hazelton (AOML/HRD)**
- **Corey Potvin (NSSL)**
- **Jimmy Correia (NWS/AFS/ANB)**

*Co-Chair ***

CAM WG Accomplishments & Challenges

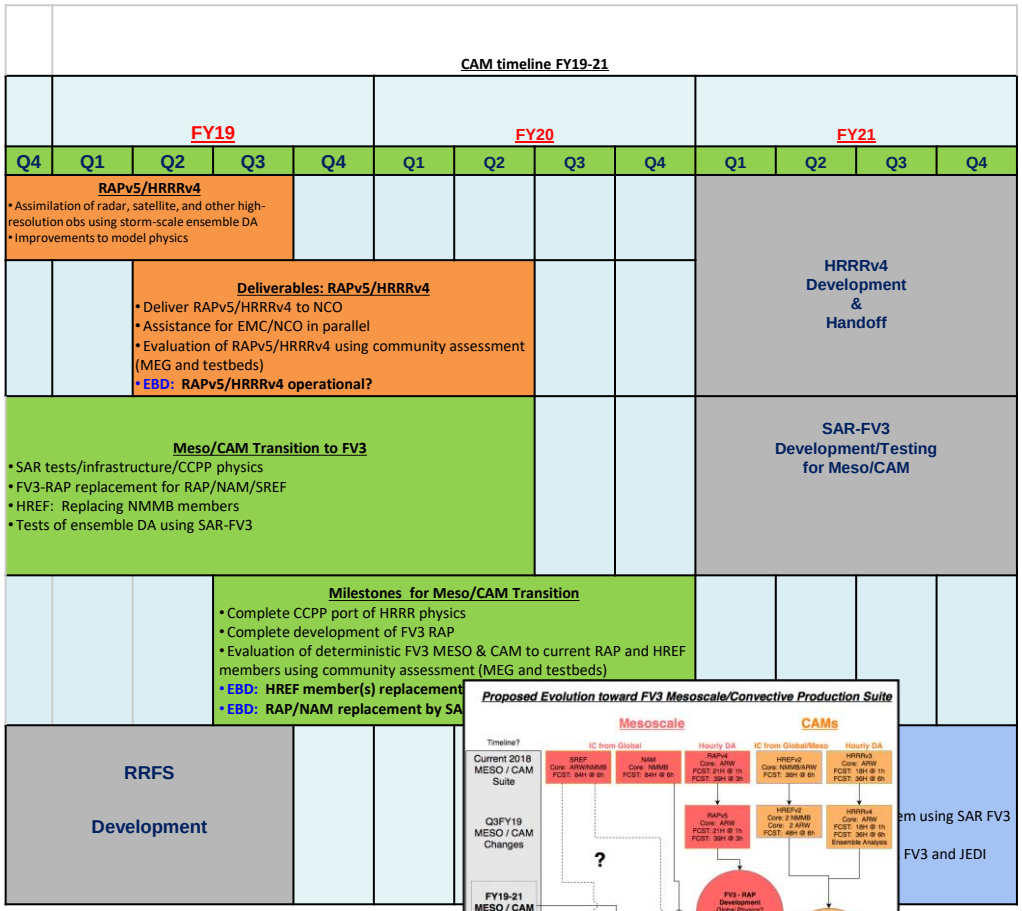
- **SIP project milestones completed/progress to date:**
  - RAPv5/HRRRv4 on track - includes CAM ensemble DA
  - Real time testing @ 3 km: FV3-Nest, FV3-SAR (**S**tand **A**lone **R**egional), and FV3-SAR with DA
    - Nest and FV3-SAR to be evaluated at HWT and FFaIR
    - National SOO Team starting to look at FV3-SAR and provide feedback
    - Evaluation in HWT and FFaIR
  - HREFv3 prototype testing underway (include FV3-CAM+HRRR members, remove HiResW NMMB member)
    - Evaluation in HWT and FFaIR
  - FV3-SAR ensemble DA infrastructure development is well underway
  - Begin physics testing (HRRR physics in CCPP; MYJ turbulence and FA Microphysics in process)
  - Begin refinement of vertical resolution and model top
- **SIP project issues (main challenges):**
  - Delay in CCPP acceptance has lead to delays in physics testing
  - Compute/disk needs are rapidly expanding and outpace available resources: CAM ensemble DA and prediction is expensive
  - Government shutdown delayed R&D HPC upgrades (OS/software and batch systems) into March-April and start of HWT Spring Forecast Experiment
  - SAR CAM workflow software coordination between collaborators (repo plan will help)

FY19-21 SIP CAM Annex

Project 7.1: Implementation of the RAPv5/HRRRv4 CAM ensemble analysis and hybrid deterministic HRRR forecast system

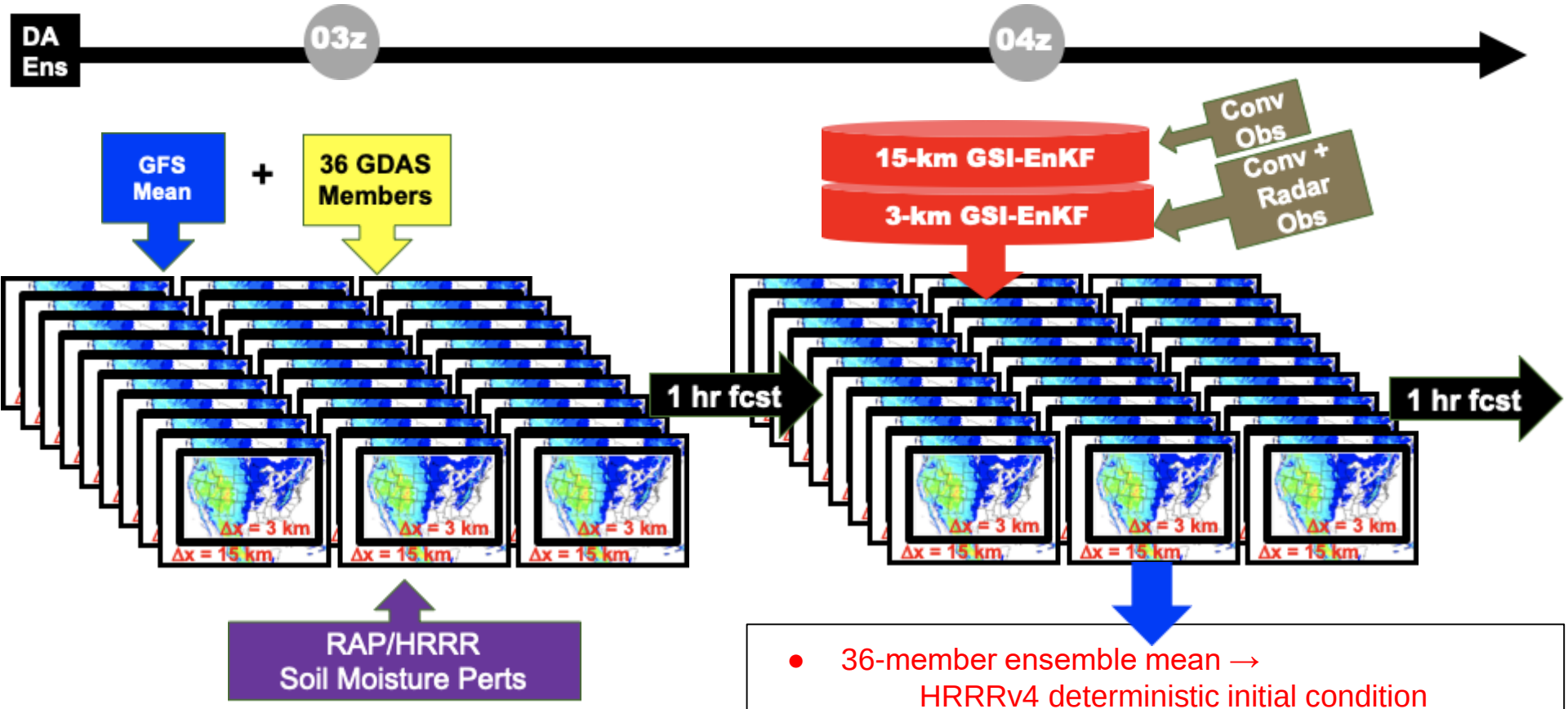
Project 7.2: Development of a SAR FV3 Meso/CAM replacement systems for NAM/RAP/HREF-Member

Project 7.3: Developing a full CAM-scale ensemble DA and prediction system based on the SAR FV3 system



Target FY22 for Rapid-Refresh Forecast System (RRFS) based on SAR FV3 and JEDI to replace NAM/RAP/HRRR/HREF

Project 7.1: RAPv5/HRRRv4 Implementation: HRRRDAS
GSD and EMC



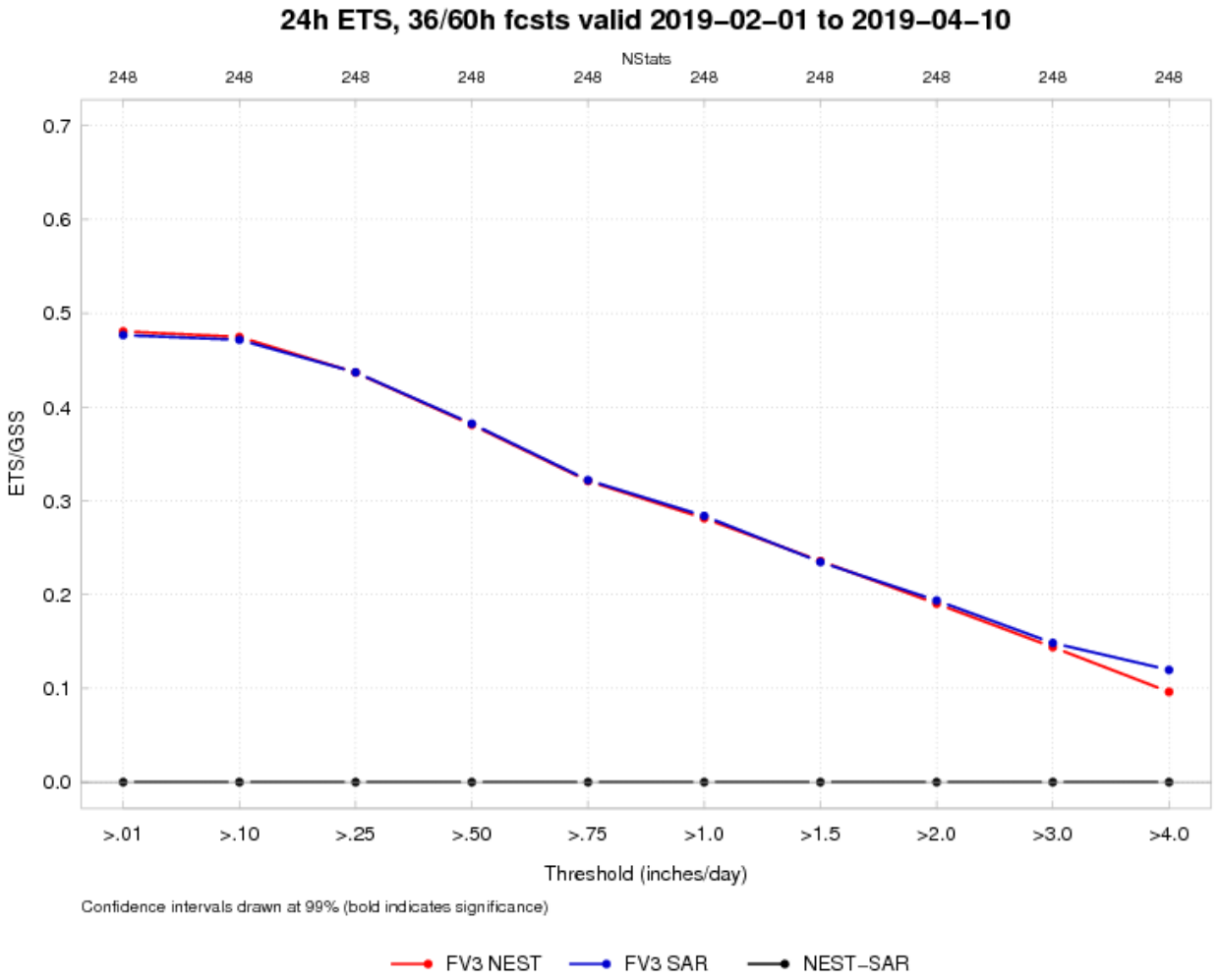
- 36-member ensemble mean → HRRRv4 deterministic initial condition
- 36-member background error covariance → HRRRv4 deterministic hybrid analysis
- 9-member HRRRE ensemble forecast (0-36hrs) → Single-model CAM ensemble (w/SPP physics)
- 9-member HRRRE lateral boundaries for WoFS
- 36-member HRRRE initial condition for WoFS

Project 7.1: RAPv5/HRRRv4 Implementation
GSD and EMC

Model	Data Assimilation	Land-surface / post
WRF-ARWv3.9+ incl. phys changes ***Physics changes:*** **MYNN PBL update – better sub-grid clouds, improved EDMF mixing** **- remove limit for subgrid qc/qi** **- decrease subgrid qc/qi radii** **RRTMG modifications for subgrid clouds** **Aerosols sources/sinks – fire/smoke, dust - Add smoke with VIIRS FRP** **Improved land-surface/snow model including better 2m T/Td diagnostics** **Latest Grell-Freitas conv (RAP only)** **Lake model for small lakes** **Enhanced gravity-wave drag** ***Numerics changes:*** **Reduced 6th order diffusion inc. hydrom** **Removal of mp_tend_lim** **Implicit-explicit vertical advection**	**Merge with GSI trunk – 2019** ***New Observations for assimilation:*** **GOES-16 radiances, GLM lightning, CrIS/ATMS** **TC vitals for trop cyclone location/ strength** **Satellite-based AOD (aerosol optical depth)** **Aircraft/raob moisture obs for p<300 hPa** **VIIRS/MODIS fire radiative power** ***Assimilation Methods:*** **HRRR - 3km ensemble DA (36 mems out to 1h)** **HRRRDAS mean for HRRR IC and BEC**	**Switch to MODIS albedo (higher), replace 1-deg albedo.** **Add zenith-ang albedo adj** **15" resolution land use data** **Fractional sea/lake ice concentration** **FVCOM data for Great Lakes lake temp/ice concentration** **VIIRS/MODIS/GOES fire radiative power** **HAILCAST diagnostic**

Project 7.2: FV3-Nest vs. SAR
EMC

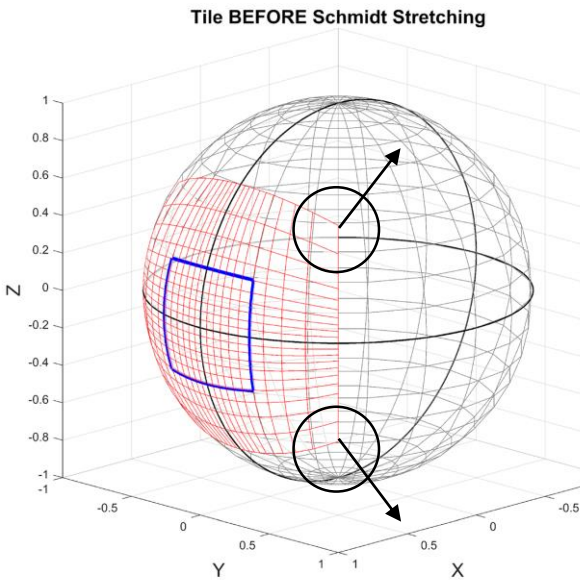
- FV3NEST vs SAR runs at 3km show *no statistically significant differences in QPF*
  - Confidence that SAR configuration is correct with no major issues
- Next steps:
  - Extending the analysis into the lateral boundaries for consistency
  - Blending algorithms

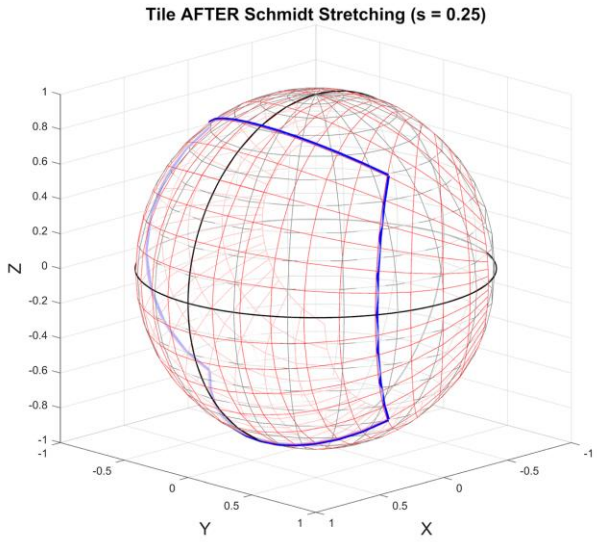


Project 7.2: Modification of the Gnomonic Grid
EMC and GSD

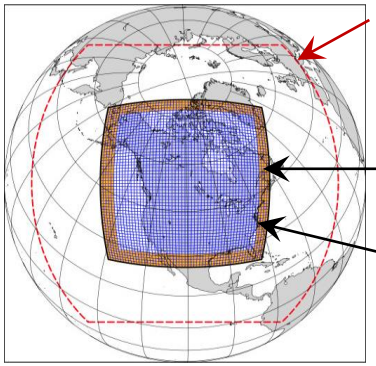
GSD collaboration with EMC (Jim Purser):

- Concentrate model coordinates (great circles) near center of tile six to improve uniformity after stretching
- Added two plotting parameters (alpha and kappa) to the generation of the gnomonic grid
- Flares the corners of the grid to reduce grid variability





Blue represents the outline of the SAR grid (tile seven) with the sixth tile of the global FV3 in red

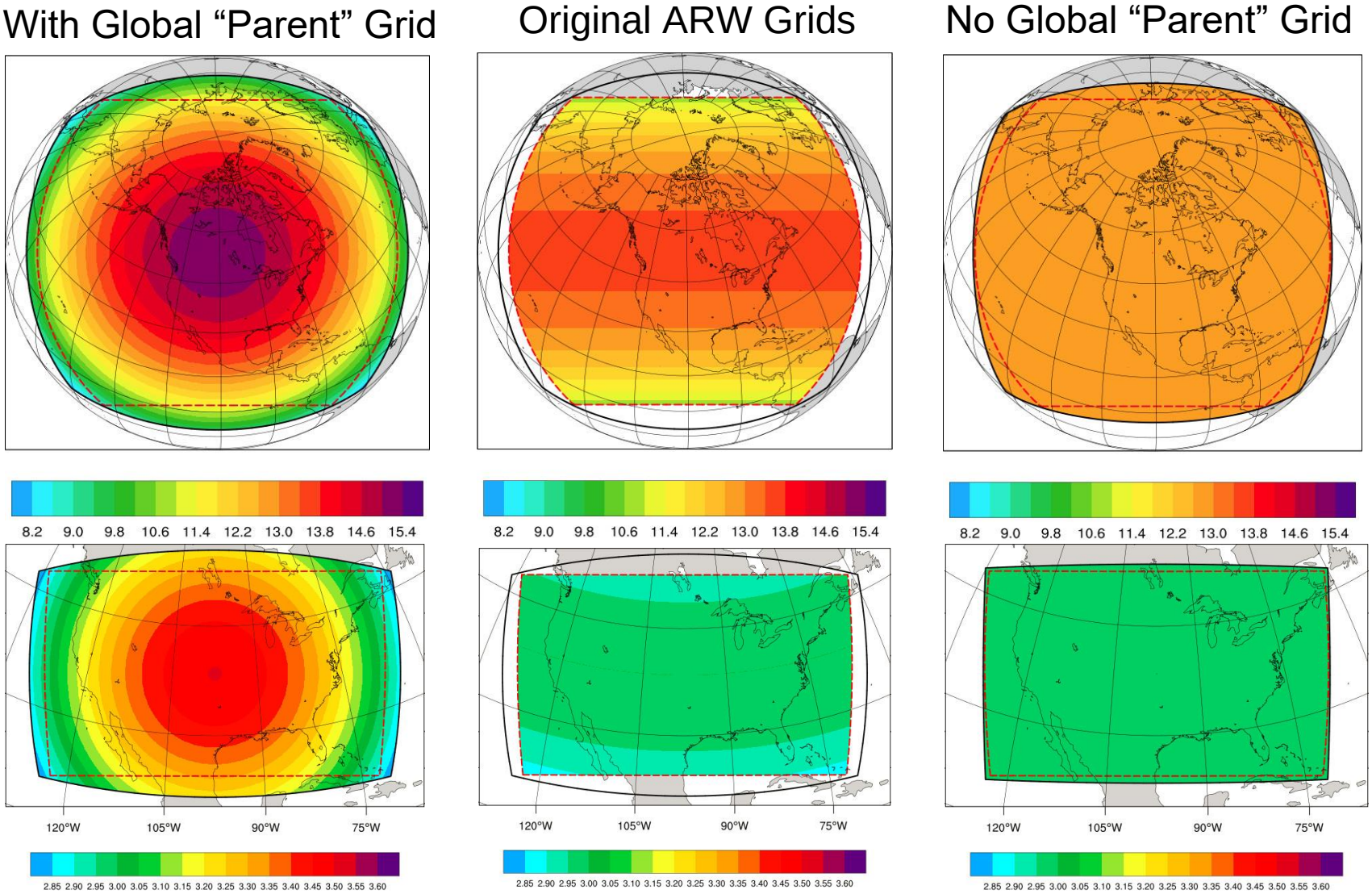


RAP/NAM Domain

Blending zone still needed with LBCs provided from external/offline model source

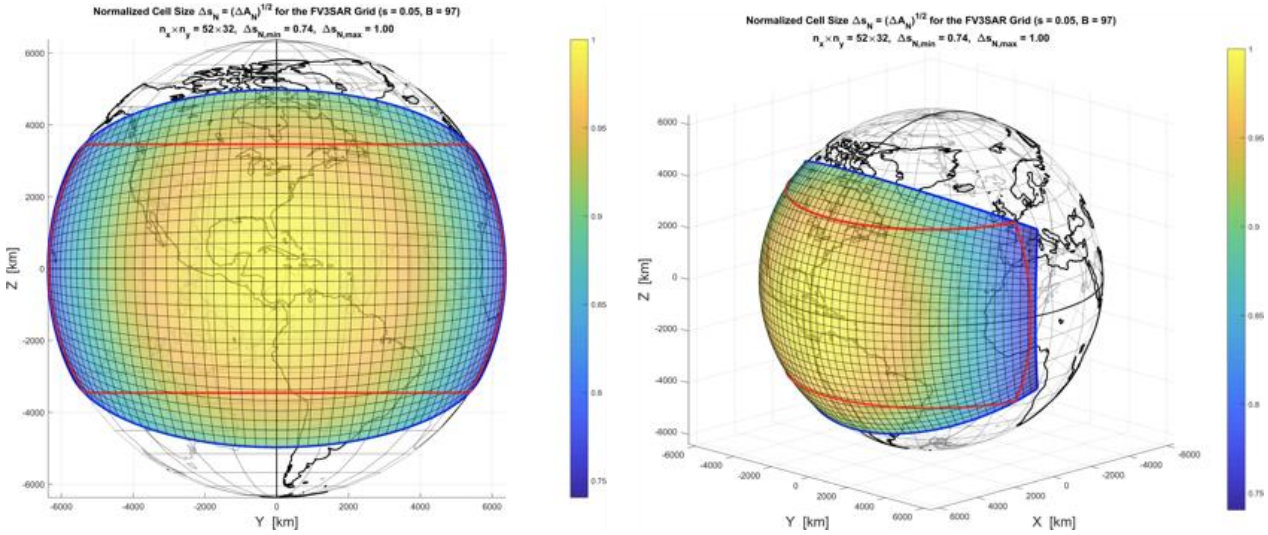
SAR integration grid (tile 7)

Project 7.2: SAR FV3 on Gnomonic Grid GSD and EMC

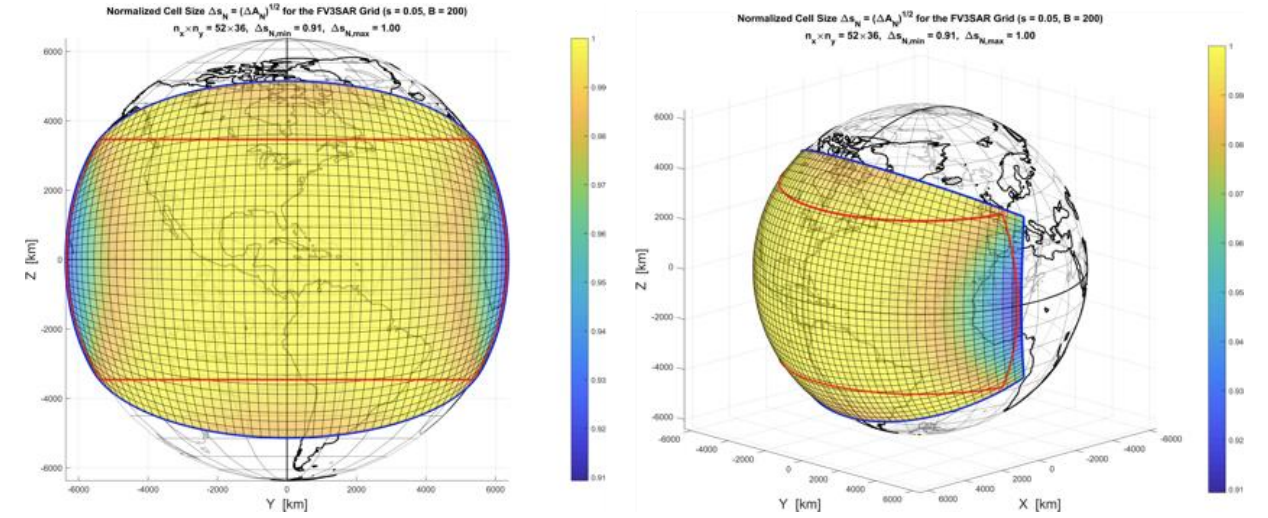


Project 7.2: Testing SAR-FV3 for Tropics
EMC, AOML, GFDL and GSD

Example 50 gridpoint configuration that minimizes grid-cell aspect ratio differences



Example 50 gridpoint configuration that minimizes grid-cell grid-cell area variance



Project 7.2: Testing SAR-FV3 for Tropics
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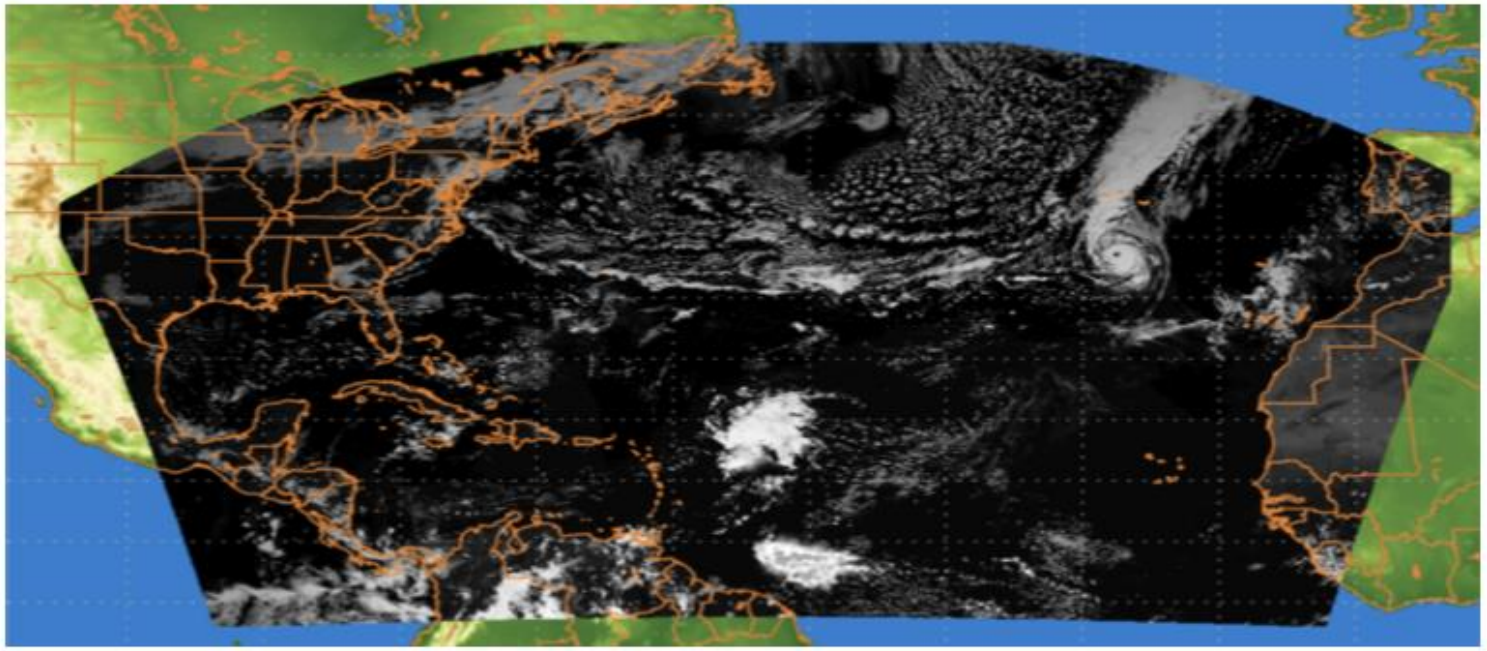
HFIP Summer Demo Experiments:

Nested 3-km FV3 GFS



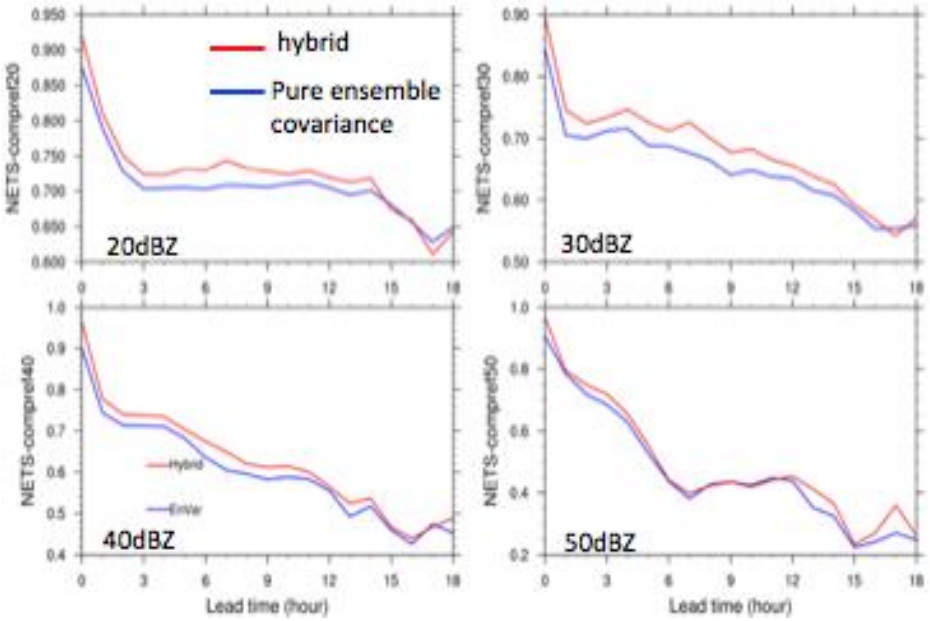
1. **HAFS v0.A** – A FV3 SAR configuration, analogous to the CAM FV3 SAR configuration, but for TC regions of interest.
2. **HAFS v0.B** – A FV3 nest within the FV3 global model (as shown above)

GSD offering to provide additional HAFS FV3 SAR forecasts with RAP/HRRR "continental CAM" CCPP physics suite

Image courtesy of Andrew Hazelton (NOAA/AOML/HRD).

Project 7.1/7.2: Hybrid Ensemble-Variational Data Assimilation Development over CONUS for HRRR/HRRRE, R2O efforts and Plan for FV3-SAR and JEDI (xuguang.wang@ou.edu and OU MAP group)

Neighborhood ETS for comp. reflectivity



- ❑ Major results from retro. experiments:

1) Direct assimilation of reflectivity outperforms cloud analysis (not shown, see Duda et al. 2018, MWR)
2) Upper figure: Hybrid (red line) outperforms pure ensemble covariance (blue line) during the 18-hr forecast period for precip and reflectivity.

- ❑ The GSI hybrid DA system (hybridization of EnVar, EnKF and static covariance) is further developed for convective scale data assimilation and tested over CONUS for HRRR model (Wang et al. 2019)
- ❑ Major developments include

1) Direct assimilation of radar reflectivity and radial velocity in the EnVar and EnKF components of hybrid (Johnson et al. 2015; Wang and Wang 2017, MWR)
2) Further develop the static covariance component of the hybrid DA system to be suitable for convective scales and radar DA (Wang and Wang 2018)

- ❑ R2O efforts:

1) new codes are officially accepted in GSI master.
2) Real time demonstration at HWT
3) GSD is testing for transition to NWS through HRRRv4

- ❑ Plan to transition and test with FV3-SAR and JEDI, if funded

Project 7.2: CAPS Efforts Enhancing and Evaluating SAR-FV3

- **Implemented physics schemes into official version of FV3 in Github via CCPP**
  - Scale-aware YSU (saYSU) PBL, Tiedtke cumulus, NSSL microphysics
  - Uses NEMS framework and supports both global and SAR FV3
  - Passes regression tests on both NOAA and TACC Stampede II HPCs
  - Used in multi-physics SAR-FV3 CAM ensembles during 2019 HWT SFE:

member	IC/LBC	Microphysics	PBL	SFC layer	LSM	Model
cntl	NAMa/NAMf	Thompson	saMYNN	GFS	NOAH	SAR-FV3
pbl1	NAMa/NAMf	Thompson	saYSU	GFS	NOAH	SAR-FV3
pbl2	NAMa/NAMf	Thompson	EDMF	GFS	NOAH	SAR-FV3
mp1	NAMa/NAMf	NSSL	saMYNN	GFS	NOAH	SAR-FV3
mp2	NAMa/NAMf	Morrison-G.	saMYNN	GFS	NOAH	SAR-FV3
lsm	NAMa/NAMf	Thompson	saMYNN	GFS	RUC	SAR-FV3
sfc1	NAMa/NAMf	Thompson	saMYNN	MYNN	RUC	SAR-FV3
globalgfs	GFSa/N.A.	Thompson	saMYNN	GFS	NOAH	nested-FV3
sargfs	GFSa/GFSf	Thompson	saMYNN	GFS	NOAH	SAR-FV3

Project 7.2: Some Hazardous Weather Testbed Goals

- Test and evaluate suites of newly implemented CCPP physics in latest SAR-FV3
- Evaluate performance of SAR-FV3 for convective-scale forecasting
- Optimize SAR-FV3-based CAM ensemble
- Compare SAR-FV3 performance with similarly configured WRF
- Assess the impact of LBC updating and use of GFS IC/LBC (global nest v.s. SAR)

Zhang, C., M. Xue, T. A. Supinie, F. Kong, N. Snook, K. W. Thomas, K. Brewster, Y. Jung, L. M. Harris, and S.-J. Lin, 2019: How Well Does the FV3 Model Predict Precipitation at a Convection-Allowing Resolution? Results from CAPS Forecasts for the 2018 NOAA Hazardous Weather Testbed with Different Physics Combinations. Geophys. Res. Lett., 46, 3523-3531.

Snook, N., F. Kong, K. Brewster, M. Xue, K. W. Thomas, T. A. Supinie, B. Albright, and S. Perfater, 2019: Evaluation of Convection-Permitting Precipitation Forecast Products using WRF, NMMB, and FV3 Models for the 2016-2017 NOAA Hydrometeorology Testbed Flash Flood and Intense Rainfall Experiments. Wea. Forecasting, Accepted.

Project 7.2: Implementation of External IC/BCs into the SAR-FV3 EMC, NSSL and GSD

- `chgres` – EMC's software package to generate IC/BCs for the SAR-FV3 running the GFS physics suite
- Collaboration with NSSL and EMC to modify `chgres` to generate SAR IC/BCs from RAP GRIB2 data
- Generated tables to map from RAP/HRRR (or other external model) to FV3 variables for multiple physics:

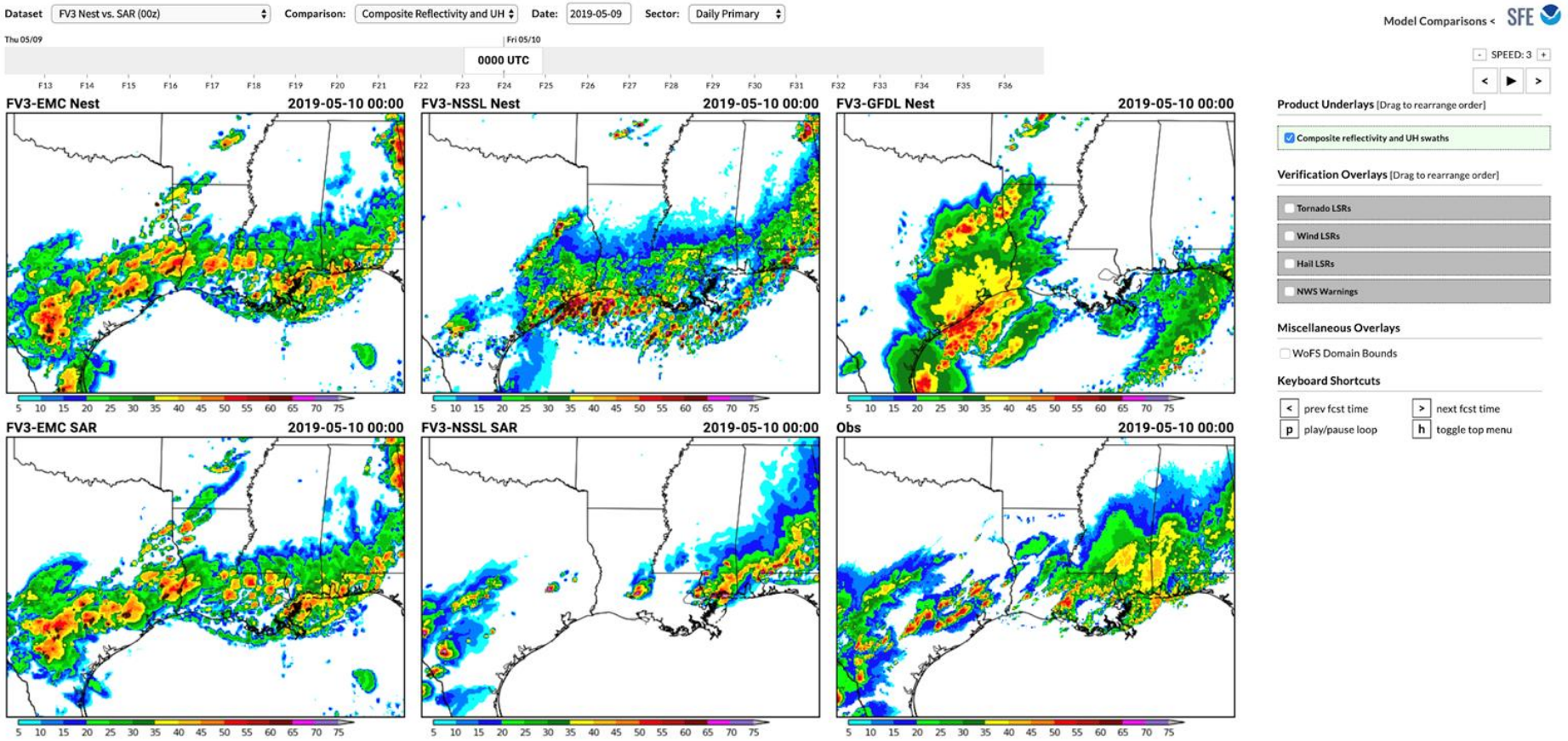
```
external_model_var(1)    FV3_model_var(1)    missing_var_method(1)    fill_value(1)
external_model_var(2)    FV3_model_var(2)    missing_var_method(2)    fill_value(2)
external_model_var(3)    FV3_model_var(3)    missing_var_method(3)    fill_value(3)
...
external_model_var(N)    FV3_model_var(N)    missing_var_method(N)    fill_value_var(N)
```

  - `missing_var_method(j)` can be "stop", "skip", or "set_to_fill_value"
  - `fill_value(j)` is the value to use if `missing_var_method(j)` is set to "set_to_fill_value".

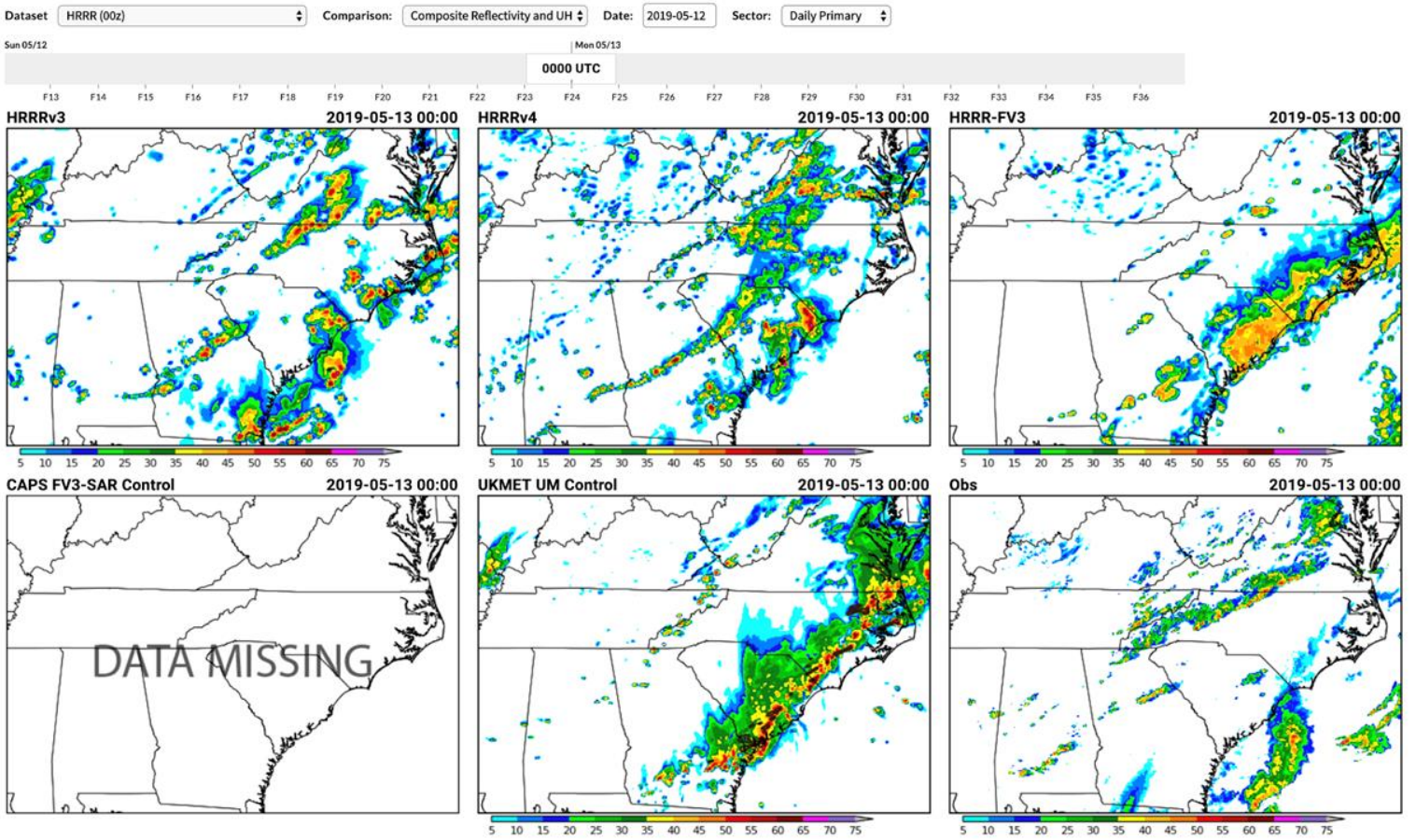
- EMC, NSSL, CAPS, GFDL and GSD providing FV3 CAM nests and/or FV3 CAM SAR for HWT SFE:

Lab/Org	Nest/SAR	Initial Conditions	Boundary Conditions	Physics Suite
EMC	Nest/SAR	GFS	GFS	GFS
NSSL	Nest/SAR	GFS	GFS	RAP/HRRR
CAPS	Nest/SAR	GFS/NAM	N/A	Various
GSD	SAR	HRRRX	RAPX	RAPX/HRRRX via CCPP
GFDL	Nest	GFS	N/A	GFDL

Project 7.2: HWT Evaluations of SAR-FV3 EMC, NSSL and GFDL

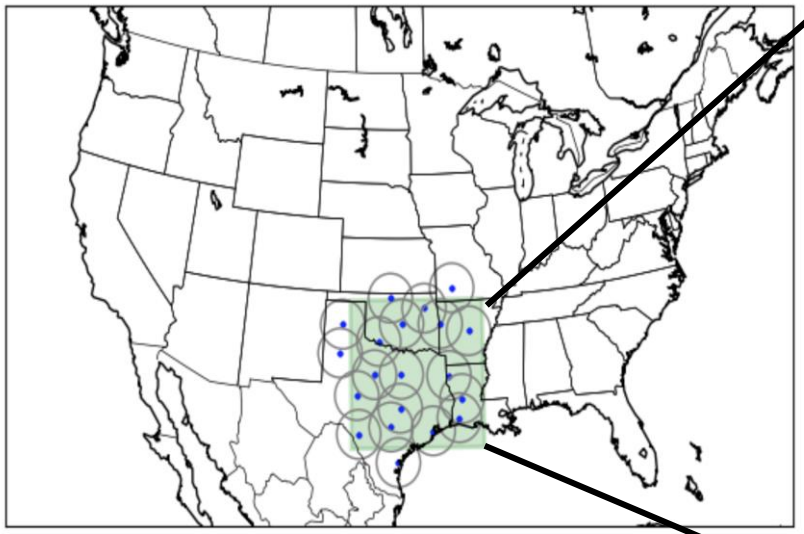


Project 7.2: HWT Evaluations of SAR-FV3
GSD, NSSL and EMC

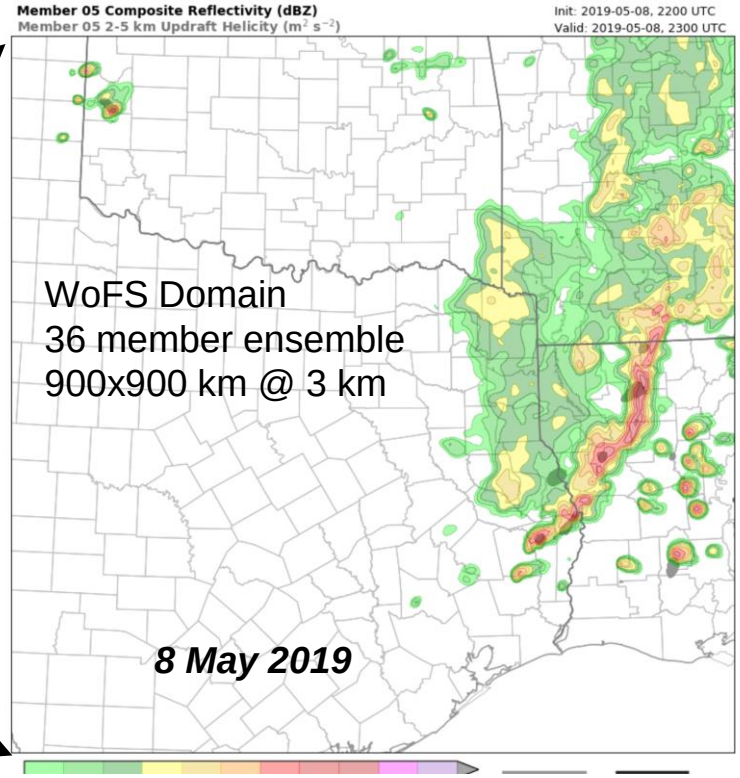


WoFS Demonstration
GSD and NSSL Collaboration

3-km HRRRE background and nested experimental WoFS grid



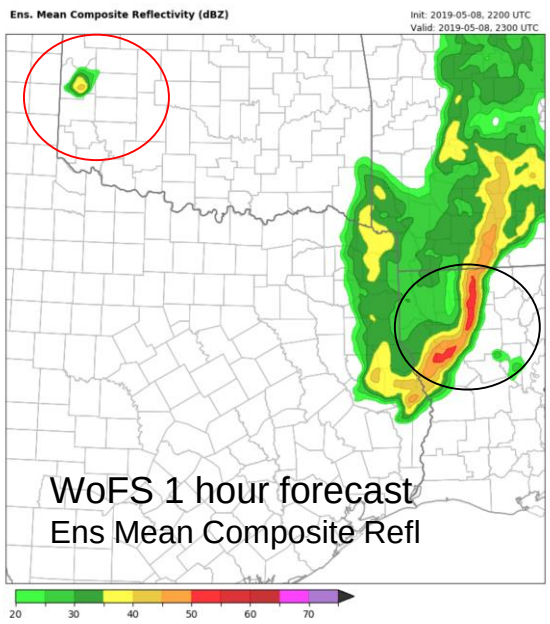
Radar locations within experimental WoFS grid shown as blue dots with 150-km range rings

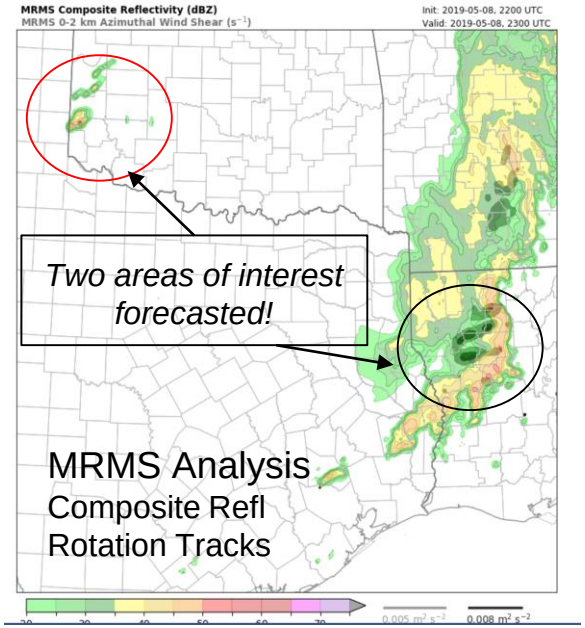


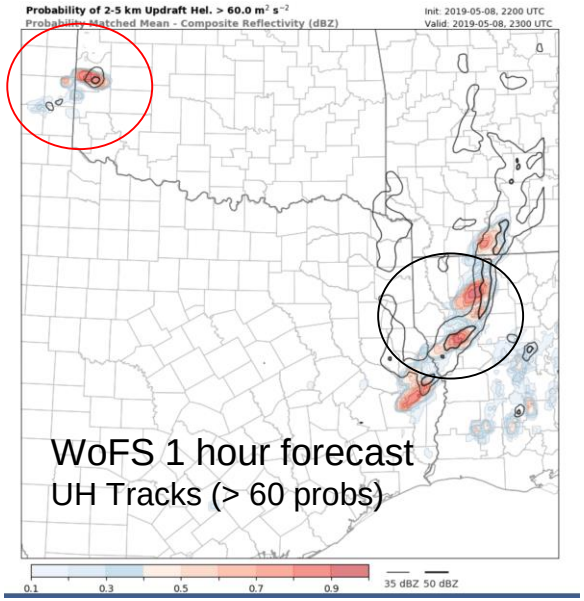
WoFS

- 3rd spring running real-time nested within GSD's HRRRDAS + HRRRE
- 6-hour forecasts generated 2x per hour for 8 hours each day
- 2nd year being formally evaluated by forecasters in Hazardous Weather Testbed's *Spring Experiment*
- Evaluated last year in the FFAIR experiment at WPC for flash flooding

HRRRE to WoFS Demonstration
GSD and NSSL Collaboration







WoFS

- SAR FV3 testing begins this summer
- Initial tests will start from WoFS analyses - regenerate forecasts
- Planning on using JEDI EnKF system for WoFS SAR FV3
- Testing of WoFS in SAR FV3 by 2021?

CAM WG Team Coordination and Dependencies

- Major team coordination/dependency successes or issues
  - Meet bi-weekly and excellent collaboration within CAM WG
  - Coordination with V&V WG over past year on CAM metrics
  - Coordination with Dynamics/Nesting WG on HAFS planning
  - Coordination with Architecture/Infrastructure on repo/coupling discussions
  - Coordination with DTC on UFS CAM support planning
  - More coordination desired with Physics and DA working groups
- What project(s) should be accelerated (due to criticality to overall effort, dependency from another area, etc.)?
  - SIP Data Assimilation Project 6.5: Global Rapid Refresh (retire mesoscale models)
- Based on experience to date, what change(s) do you recommend to your working group?
  - Governance of CAM WG membership: How do we maintain sufficient community cross-section while keeping manageable group size? Can/should we remove inactive participants?